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Mapping socio-spatial segregation in the city of Marília/SP (Brazil)

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ABSTRACT

Urban segregation represents a significant barrier to achieving social inclusion in cities. Its cartographic representation is important to measure the evolution of this serious urban phenomenon. This paper aims to map the susceptibility to socio-spatial segregation in Marília/SP (Brazil). The method of calculating the informative value and susceptibility was adapted to measure the segregation of the urban area of the city. As per the final map validation, the success rate was 93%; this methodological adaptation presented great potential and can contribute to the urban planning activities. Keywords: socio-spatial segregation, informative value, geoprocessing, Geographic Information System (GIS).

Mapeamento da segregação socioespacial na cidade de Marília/SP

RESUMO

A segregação urbana representa uma barreira significativa para a inclusão social nas cidades. Sua representação cartográfica é fundamental para dimensionar a evolução desse grave fenômeno urbano. O objetivo do artigo é mapear a suscetibilidade à segregação socioespacial de Marília-SP. A metodologia de cálculo do valor informativo e suscetibilidade foi adaptada para mensurar a segregação da área urbana da cidade. Como a validação do mapa final, a partir da taxa de sucesso, foi de 93%, considera-se que essa adaptação metodológica apresentou ótimo potencial e pode contribuir nas atividades de planejamento urbano.

Palavras-chave: segregação socioespacial, valor informativo, geoprocessamento, Sistema de Informações Geográficas (SIG).

Introduction

Urban socio-spatial segregation represents a barrier to the development of inclusive cities, as it reinforces social exclusion (Un-Habitat, 2001). Urban space segregation, exclusion, and division are central issues for Sociology, Geography, Anthropology, and Urban Planning (Habeck and Belolyubskaya, 2016; Schuermans, 2016).

Regardless the urban analysis approach, cities can be assessed from their geometric structure. Economic, social, and roadway aspects, for example, are articulated in spatial terms, and

their effects are expressed in urban land use features (Mesev et al., 1995).

Although the socio-spatial segregation can be considered a category of analysis inherent to metropolitan regions (Caldeira, 2000; Sposati, 1996, 2001; Marques and Torres, 2011; Villaça, 2001), it was also discussed in small and medium-sized cities (Amorin Filho, 2005; Feitosa et al., 2007; Mellazzo, 2006; Sposito, 2007). Medium-sized cities represent a combination of demographic size, urban functions, and intra-urban space organization that

characterizes them as a differentiated study object.

The premise of the study is that the production of space by social agents materializes in the form of spatial patterns and that this segregated pattern is visible through residential areas. Its objective is to map the susceptibility to socio-spatial segregation of the population of Marília/SP (Brazil). The methodological proposal consists of adapting procedures for the calculation of informative value and bivariate statistics (Yin, 1988, Yan and Yin, 1988). The map of segregation susceptibility was classified according to the parameters proposed by Chung and Fabbri (2003) and evaluated according to the Success Rate curves proposed by Remondo et al. (2003).

Foundations

Conceptual

Socio-spatial segregation, or physical separation of social groups, is the result of differentiation into two basic plans: geographical, since space is diverse and unequal in its characteristics; and social, because the unequal distribution of wealth produces a social system in classes (Alves, 2013).

Brazilian cities were formed under the same State and historical moment, and because they contain the same social formation, common traits of the intra-urban organization are present. Currently, theoretical models, such as the concentric circle model (center-periphery development), do not seem to be appropriate to explain neighborhood layout and the segregating structure of intra-urban space.

(...) the most powerful (but not the only) force acting on the structuring of intra-urban space has its origin in the class struggle for the differentiated appropriation of the advantages and disadvantages of the space constructed in the resulting spatial segregation. This, as will be shown, is a necessary condition for the exercise of domination through intra-urban space. (Villaga, 2001, p. 5 - translated)

In the specific context of medium-sized cities, one part of the population is concentrated in tight urban spaces, together socio-economic inequality, infrastructure and urban services access, and strong socio-spatial segregation in most cities of developing countries generate

susceptibility to poverty and segregation. In the city, unequally susceptible spaces spatially translate socioeconomic inequalities between neighborhoods and/ or communities (Pascoalino and Moraes Pereira, 2009).

The concept of susceptibility is widely used in geo-environmental studies, especially with regard to natural phenomena, such as landslides, floods, etc. In this paper, the concept of susceptibility proposed by Soeters and Van Westen (1996) was adopted, which is understood as the propensity of the territory to occurrences of a particular type of phenomenon in indeterminate time, based on a set of predisposition factors. Adapted to the study object of this article, the susceptibility will be considered as the propensity for the occurrence of socio-spatial segregation in the city of Marília / SP, based on a set of social factors of the population and land use and coverage existing in the city.

Methodological

The bivariate statistical method used for the evaluation of susceptibility was the Informative Value. Yan (1988) and Yin and Yan (1988) proposed a risk assessment of surface landslides.

According to Yin and Yan (1988), the method requires the prior definition of terrain units and the consideration of a set of susceptibility factors. It has a Bayesian basis, supported by the logarithmic transformation (natural log) of the ratio between conditioned probability and probability *a priori*. For each of the classes of a variable is determined the respective Information Value, from the relation:

$$I_i = \log \frac{S_i / N_i}{S / N}$$

I_i : Informational value of the variable I ;

S_i = number of land units with subnormal census tract type y and with the presence of variable x_i ;

N_i = number of land units with the presence of variable x_i ;

S = total number of land units with subnormal census tract of type y ;

N = total number of land units.

The Susceptibility Value for each pixel j was calculated by the Total Information Value obtained by the following equation:

$$I_j = \sum_{i=1}^n X_{ji}.I_i$$

Where:

n = number of variables;

X_{ij} is equal to 1 or 0, depending on whether the variable X_i is present in pixel j, respectively.

Aleotti and Chowdhury (1999) provided tools to the proposal of Yan (1988) and Yin and Yan (1988). According to these authors, the steps are: 1) cartographic selection and representation of the significant parameters grouped into the most relevant classes, 2) the inventory representation of the existing landslides scars 3) overlaying the inventory map of landslides scars with each parameter map, 4) determination of the density of landslides scars for each class of parameters and definition of weighted values, and 6) estimation of the most favorable values through bivariate relationships between the inventory map of the landslides scars and the thematic maps of the conditioning factors.

These methodological procedures (Aleotti and Chowdhury, 1999) were adapted for the calculation of susceptibility to socio-spatial segregation. The proposal of this adequacy was based on the conjunction of two main factors: conceptual and empirical.

Considering that the concept of susceptibility of Soeters and van Westen (1996) does not refer to a specific type of occurrence, and considering the susceptibility as the tendency of an area to be influenced by a certain phenomenon, according to a set of factors, it is plausible to suppose that any fact or process, physical or human, can be used in this method. From the point of view of the cartographic experience, this methodological adaptation was also feasible due to the simplicity of modeling and spatial representation of the data on urban segregation.

Thus, the steps used in this research were:

- 1) Sensitivity analysis of predisposition factors based on Pereira et al. (2012) and Piedade et al. (2011) to determine the relative importance of each factor.
- 2) Calculation of the Informative and Susceptibility Values, proposed by Yan (1988) and Yin and Yan (1988);
- 3) Mapping and reclassification of map values, based on the proposal of Chung

and Fabbri (2003);

- 4) Evaluation of the results from the success-rate criterion proposed by Remondo et al. (2003).

2.3. Procedural

The research procedures are listed below and represented by the flowchart of figure 1.

- 1) Cartographic representation of the significant parameters, that is, set of susceptibility factors for socio-spatial segregation:
 - Elaboration of a land use map of Marília/SP, based on orbital remote sensing techniques. The map was classified into homogeneous residential areas (Gonçalves et al., 2006);
 - Elaboration of indexes and social indicators such as socioeconomic, educational and environmental quality, based on data from the 2010 IBGE census;
 - Integration of land use data with socioeconomic and population data in a GIS (Geographic Information System) environment.
- 2) Sensitive analysis of each predisposition factor (Pereira et al., 2012; Piedade et al., 2011).
 - Determination of the density of the existing subnormal census tract for each thematic map and class parameters;
 - Definition of their weighted values.
- 3) Calculation of informative value and calculation of susceptibility (Yan, 1988; Yin and Yan 1988).
- 4) Image classification into continuous values of susceptibility (very low, low, medium, high, and very high), according to breaks in the geometry of the success curve (Chung and Fabbri, 2003).
- 5) A model-quality analysis using the success rate (Remondo et al., 2003).

Figure 1: Flowchart of the research procedures.

During cartographic representation of the significant parameters (phase 1), the following thematic maps were considered:

- Socioeconomic level: index composed by the number of residents per bathroom and income of the person in charge of the household (folded weight). For the thematic map, the census tracts of the municipality and the method of natural breaks of Jenks were used;
- Educational level: index composed of the number of illiterates ten years of age or older and illiterate responsible for the domicile (census tracts and natural breaks);
- Household environmental quality indicator: index consisting of the normalized average of the following variables: burnt litter, buried garbage, collected garbage, integrated sewage

network, rudimentary pit or ditch, and water supply network (census tracts and natural breaks);

- Land use map: elaborated using visual interpretation of an orbital image from the WorldView-II satellite (date of imaging: 18/08/2010). It has a spatial resolution of 2 meters in the multispectral bands and 0.50 m in the panchromatic channel (blue, green, red, near infrared, and panchromatic bands). The interpretation key considered 15 classes: tree and shrub vegetation, pasture, paving, industrial use, commercial use, institutional use, leisure use, new urban settlements, and homogeneous residential areas of types 1, 2, 3, 4 and 5.

The interpretation key was composed by:

Residential zone type 1: closed high-standard condominiums or high standard single-family houses. Large lots with swimming pool, close to the main roads of the city and urban infrastructure, having backyards with trees or landscaped elements (figure 2).

Figure 2: Example of residential zone type1.

Figure 3: Example of residential zone 2.

Residential zone type 2: closed medium-standard condominiums and average-standard single-family houses. Average-size lots close to the main roads of the city, having backyards with trees or landscaped elements (figure 3).

Residential zone type 3: single-family residences with medium-to-low standard of living. Medium size and denser lots farther from

the main roads of the city. They have no wooded backyards or landscape features. Ceramic roofs predominate (figure 4).

Figure 4: Example of residential zone 3.

Residential zone type 4: low-standard single-family houses and vertical housing developments. Lots are small with denser buildings, farther away from the city's main thoroughfares, and no backyards. Asbestos-cement roofs predominate, despite the existence of ceramic tiles imbricated in the urban fabric (figure 5).

Figure 5: Example of residential zone 4.

Residential zone type 5: minimum-standard single-family residences. Small lots of rough constructions, lack of ceramic tiles and predominance of asbestos-cement tiles.

Horizontal residences characterized by self-construction, far from the main roads of the city, with no backyards nor asphalted roads (figure 6).

Figure 6: Example of residential zone type 5.

2.4 Study Area

Marília is a municipality in the state of São Paulo, Brazil, which has an area of 1,170 km² (IBGE, 2015). It is a medium-sized city with 216,745 inhabitants (2010). The intra-urban space is X-shaped as shown in figure 7:

Figure 7: Representation of the intra-urban area of Marília-SP (Brazil).

Results and discussion

The initial results, expressed in figures 8 and 9, show the spatialization of social indexes and indicators and the land use map.

Figure 8: Indexes and social indicators of Marília-SP (Brazil).

Figure 9: Map of urban land use in Marília-SP.

Figure 10: Map of Informative Value of Marília-SP.

The informative value for each map was calculated based on the maps of figures 8 and 9. The map algebra allowed the respective addition of the weighted values, which resulted in the Map of Informative Value (figure 10).

The success rate for the map, based on the IBGE subnormal census tracts for 2010, was

then calculated according to Remondo et al. (2003) and classified according to Chung and Fabbri (2003). As shown in Figure 11, the success rate of the map was 93%.

Figure11: Methodology success rate.

Figure 12: Map of Susceptibility to socio-spatial segregation of Marília – SP (Brazil).

Figure 13: Comparisons between socio-spatial segregation susceptibility and land use maps, Marília – SP (Brazil).

The values of the final map were classified based on the said success curve (Chung and Fabbri, 2003), and the result is illustrated in figure 12.

Analyzing the susceptibility map, we noticed a trend towards the expansion of subnormal census tracts (slums) for 2010 in areas occupied by arboreal and shrub vegetation and pasture, as can be seen in figure 13.

Regarding the method for socio-spatial segregation mapping, it is worth highlighting the benefit of the result associated with small units of land (pixel), unlike most techniques that adopt predefined limits of administrative units.

It is also possible to perceive a tendency of slums to grow towards areas of private natural heritage reserve (RPPNs), which corroborates the discussions in Baptista (2008) and Mello-Théry (2011).

Measuring segregation by social indexes and indicators has been a recurrent example for

stating the separation of social classes in cities (Brown and Chung, 2006; Reardon and O'Sullivan, 2004; Wong, 1998, 1999). Most of these indexes are produced from a prior definition of segregation areas, such as dissimilarity, exposure, and variance ratio (Wong, 1993, 2002). According to Reardon and O'Sullivan (2004), the results of segregation studies are commonly limited methodologically by spatial representation of variables.

This is due to an incompatibility between these aggregation units (blocks, weighting areas, census tract, etc.) and spatial extent of the surveyed phenomena. This question, considered classic by the researchers that use spatial analysis, is called by the acronym MAUP (Modifiable Areal Unit Problem), according to Openshaw (1984).

In addition, in choosing a study area (municipalities, countries, states, etc.), the respective indicators incorporate a variety of

spatial relationships transcending administrative boundaries. These relationships vary according to the historical, technical, and administrative process of aggregation, which, in turn, directly influences segregation indexes and the mapping itself (Rey and Folch, 2011).

By using this method to map socio-spatial segregation, it is believed that the MAUP was at least partially equated, since, even though the census tract was used, the Weighted Susceptibility Value was associated with each pixel in the composition of factors of the final map.

Final considerations

Although the mapping method based on the informative value, proposed by Yan (1988) and Yin and Yan (1988), is applied mainly for the analysis of susceptibility to landslides, it showed relevant numerical results when adapted to the susceptibility to socio-spatial segregation. Using social indexes and land use map as conditioning factors, it showed a high success rate (93%) for the predictive factor of the map.

Thus, it is considered that the used method can contribute to urban planning and the direction of more efficient public policies that could somehow provide a more dignified life for the residents of the city of Marília and, perhaps, minimize urban socio-spatial segregation.

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